# Climate Change, Alteration in Plant Phenology and Allergic Diseases in the US

**National Socio-Environmental Synthesis Center (SESYNC)**

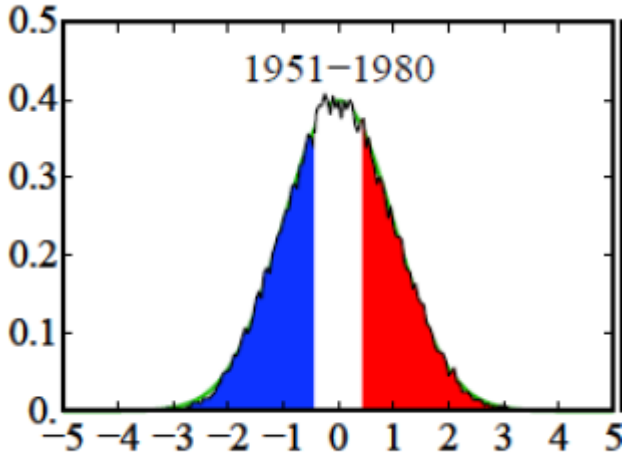
**Annapolis, MD**
**March 22nd , 2016**

Amir Sapkota, PhD
Associate Professor
University of Maryland School of Public Health

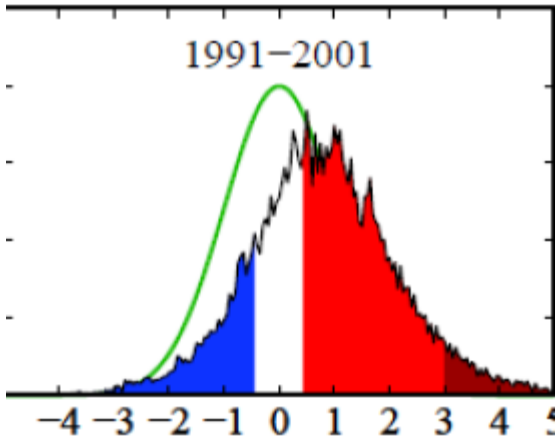
SCHOOL OF PUBLIC HEALTH

# Outline

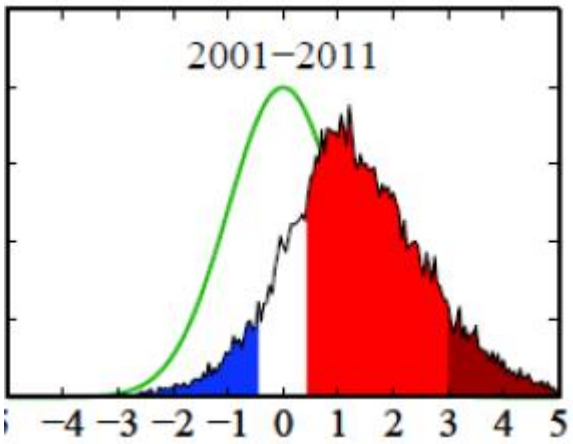
- **BACKGROUND**
  - Our changing climate
    - Extreme events
    - Alteration in plant phenology
- **NATIONAL PERSPECTIVES**
  - Changes in plant phenology and allergic rhinitis
- **LOCAL PERSPECTIVES**
  - Extreme events and Adverse Health in MD
    - Respiratory disease: Asthma
    - Cardiovascular disease: Myocardial Infarction
    - Foodborne disease: Salmonellosis
- **QUESTIONS/DISCUSSION**




Occurrence of summertime temperature anomalies over land, relative to 1951-1980, in the unit of Standard Deviation




1991-2001




2001-2011

Hansen, Sato, & Ruedy 2012

# Linking Climate Change to Health

- Challenge:
  - Climate Change: Decadal time scale
  - Most epidemiological studies last only few years.
  - How do you link health effect with something that happens in decadal scale?
- Metric we use to measure exposure:
  - Concentration
  - Duration
  - Frequency

# Framing the problem

- In response to our changing climate, extreme events will become:
  - More frequent
  - More intense
  - Longer lasting

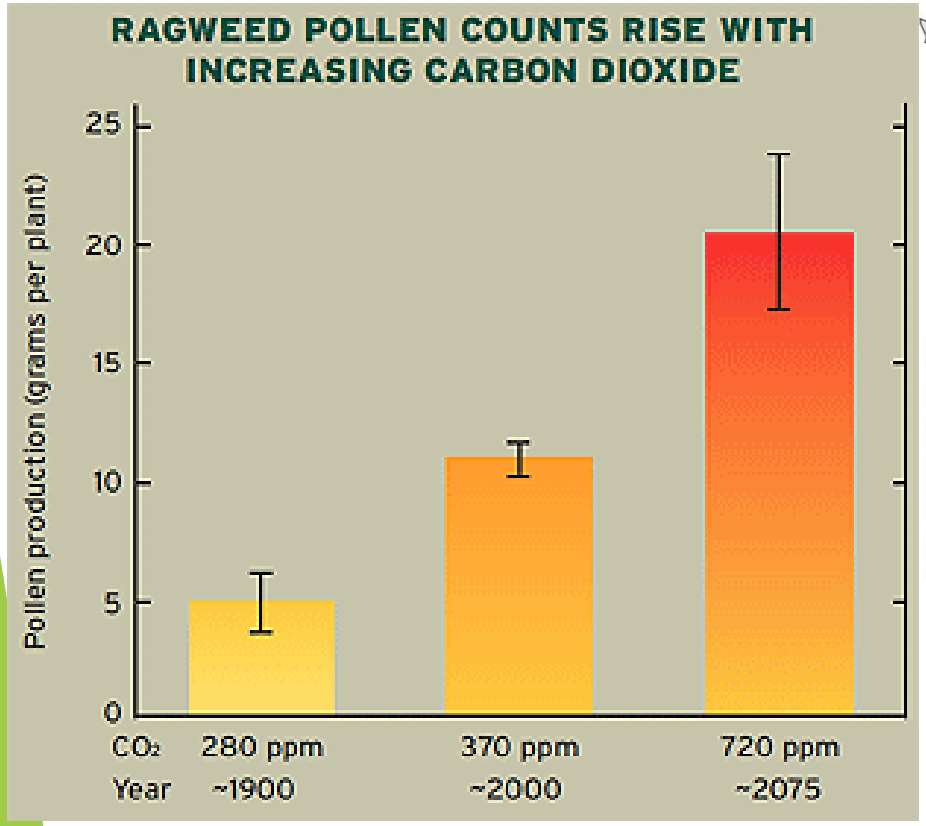
  (Field et al. 2012)

- Question: How does frequency of extreme events impact **Human Health**?

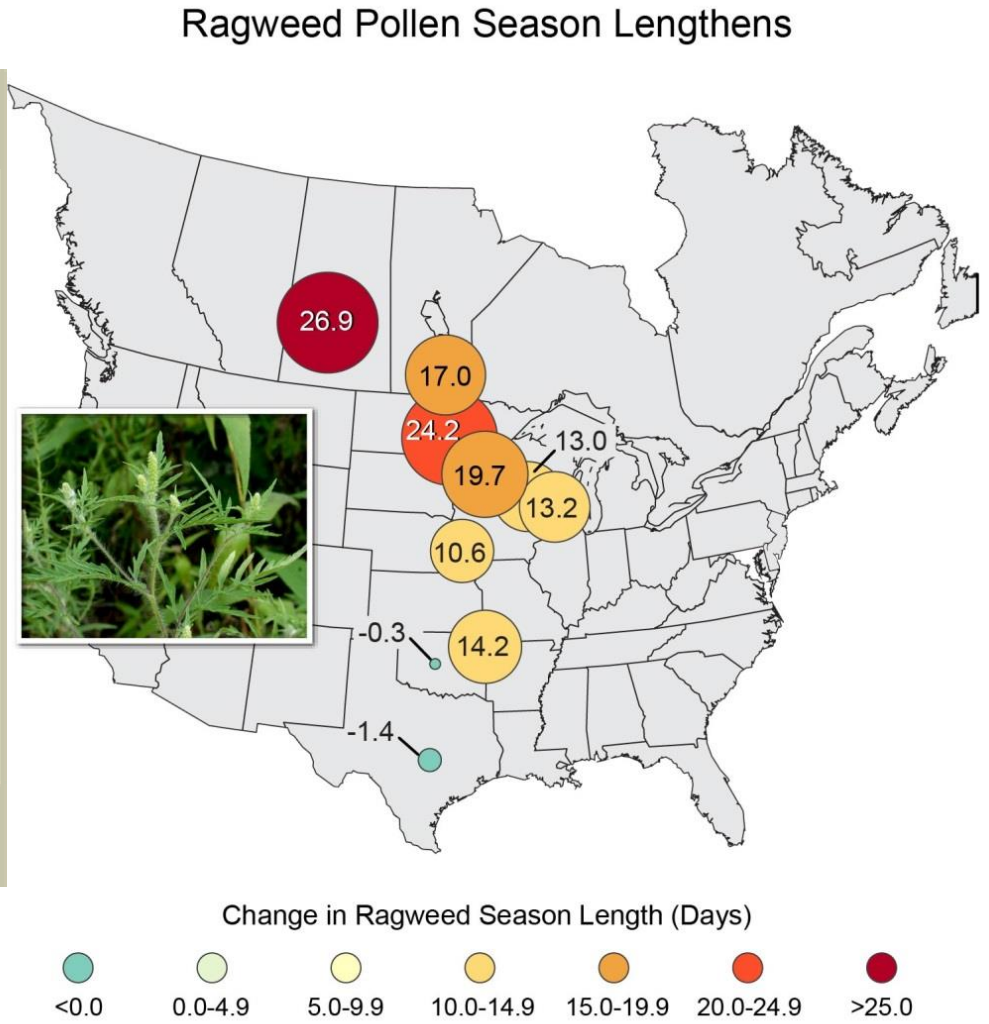
# Framing the Problem

- Plant Phenology
  - Nature's calendar
  - Timing of seed germination
  - Timing of leafing
  - Timing of particular flower blooming
  - Growing season length
  - Most sensitive indicator of ecological response to our changing climate.
- How does alteration in plant phenology impact allergic disease?

# Biological Rationale: Climate Change and Allergic Diseases



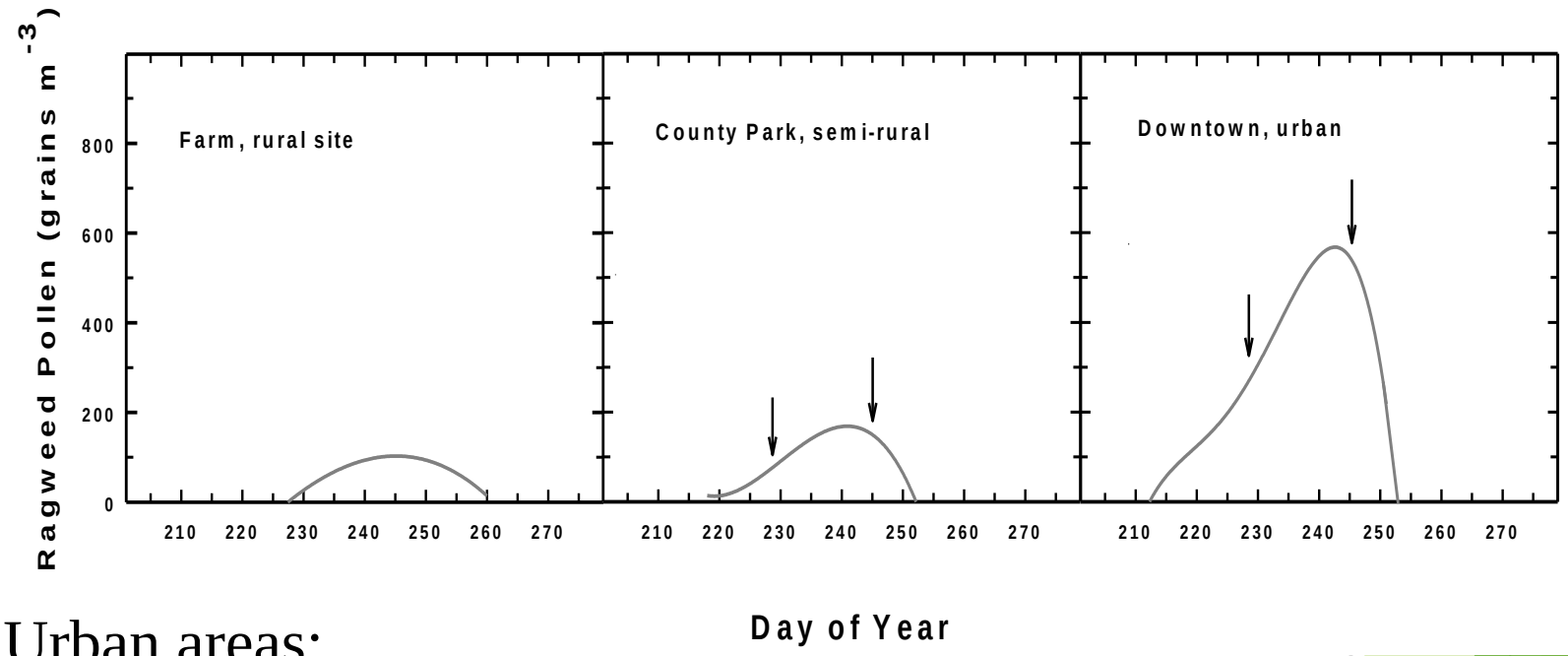

Ziska and Caulfield, 2000




Credit: Dr. Ziska, USDA
(Ziska et al. 2011)

# Biological Rationale: Climate Change and Allergic Diseases

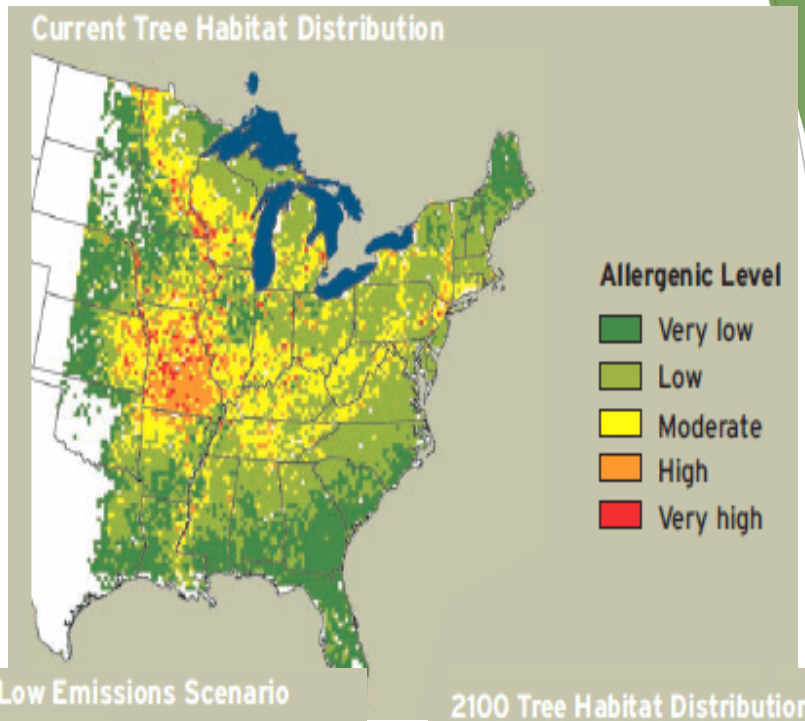
## Ragweed pollen: Results from a natural experiment

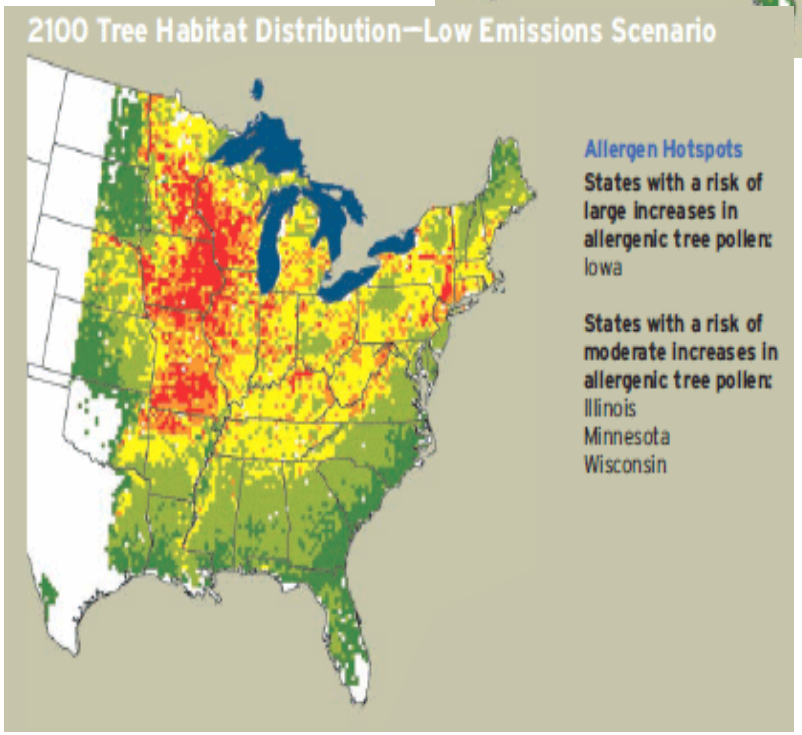


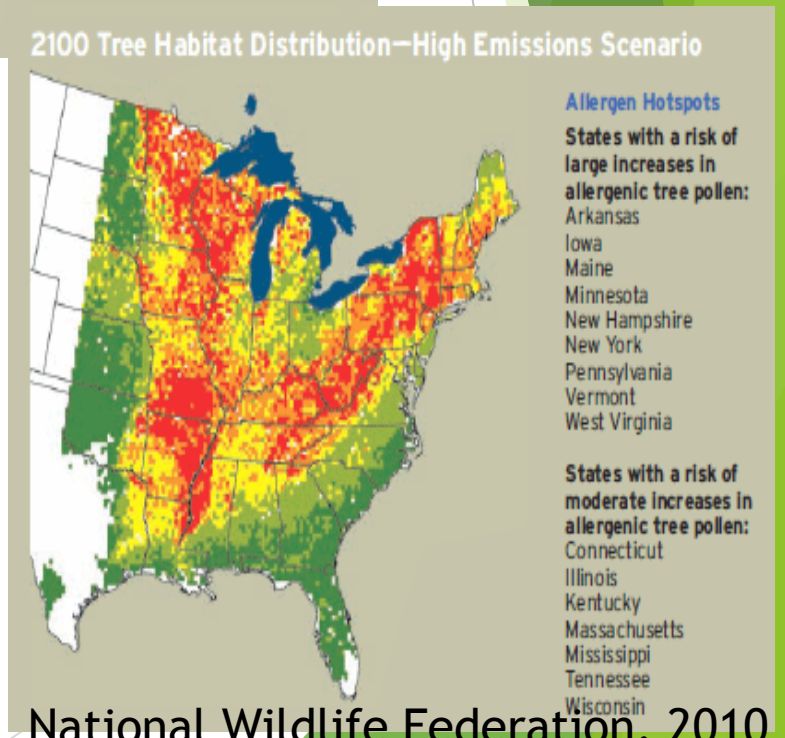

Urban areas:

- Longer growing season, and higher pollen concentration
- Warmer temperatures, and more carbon dioxide.

Credit: Dr. Ziska, USDA




National Wildlife Federation, 2010

# Research Gaps

- Link to human health
  - Need for empirical evidence on national scale (presence/absence, vulnerability, modifying factors).
- Leverage EXISTING large datasets, taking advantage of both spatial and temporal contrast

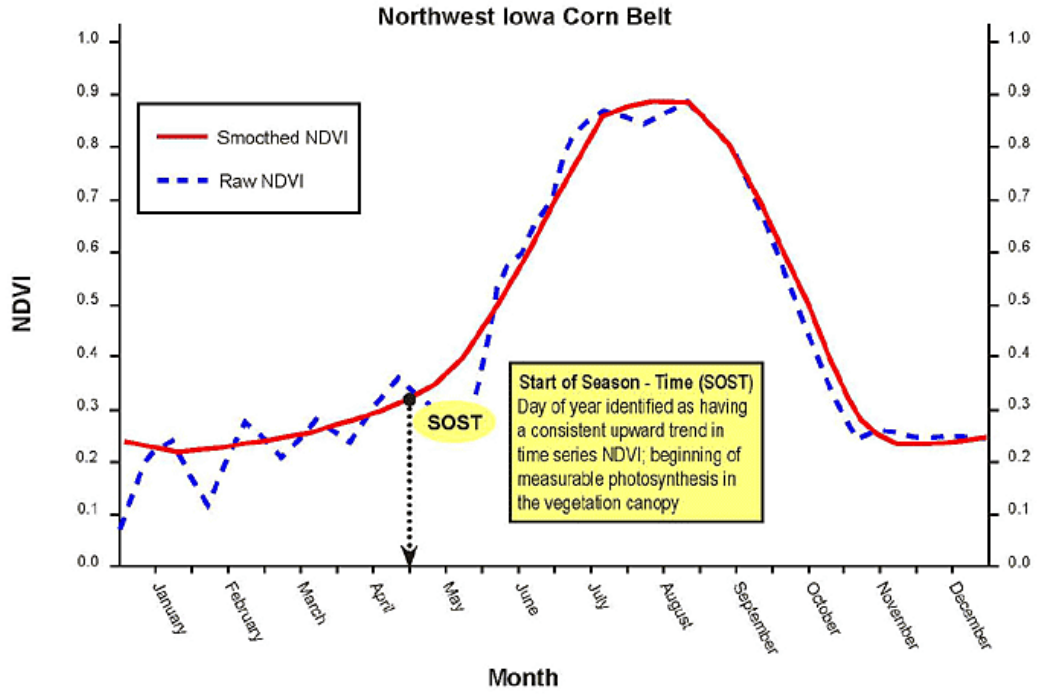
# Phenology Data

- Based on In Situ Measurements:
  - National Phenology Network
    - *Very local, different methods*

- **Based on Remote Sensing**
  - Satellite data  used for tracking seasonal changes in vegetation at local, regional, Continental and global scale.
    - MODIS
    - AVHRR

# Start of Season (Onset of Greening)

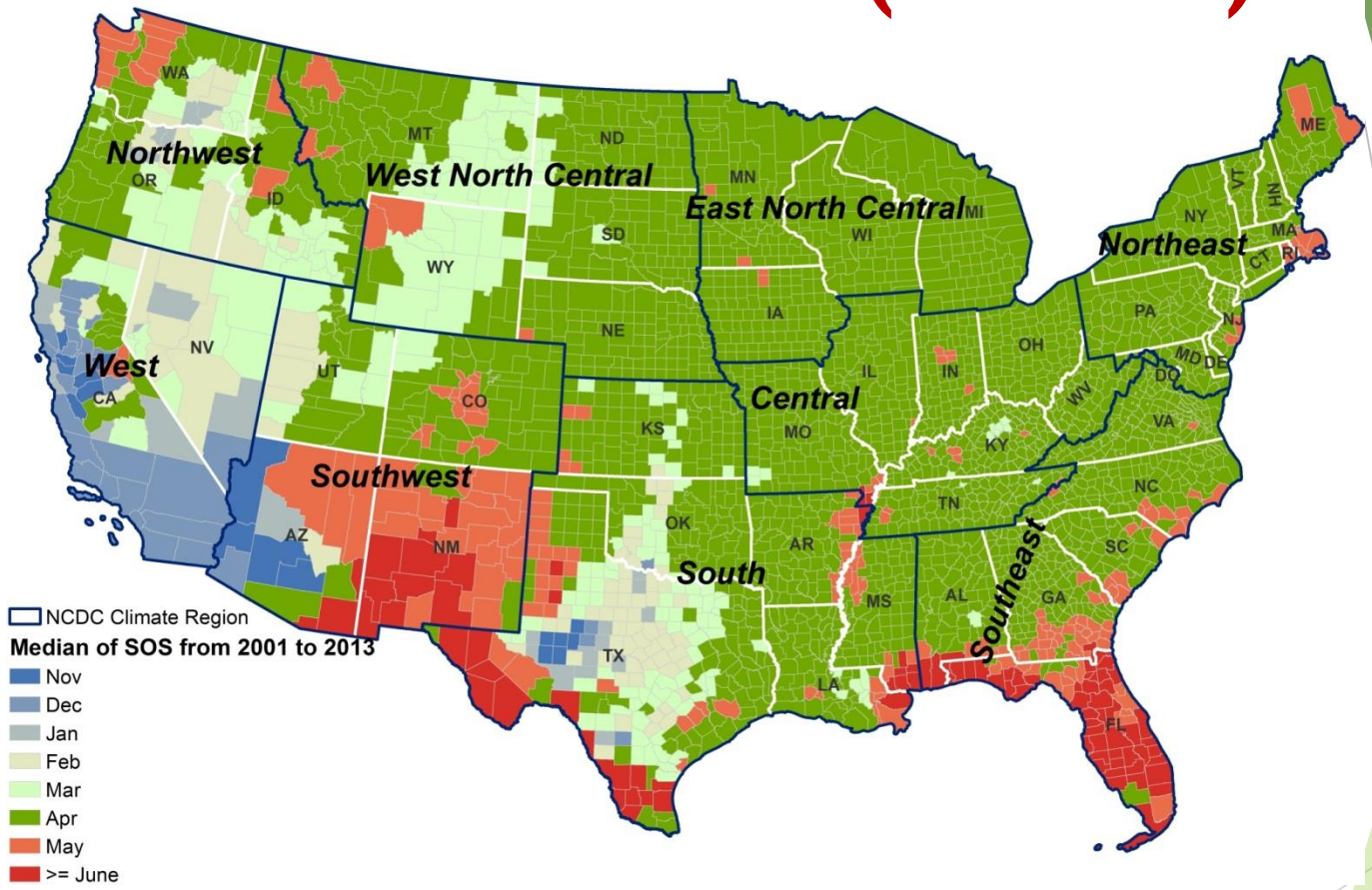







http://phenology.cr.usgs.gov/overview.php
http://phenology.cr.usgs.gov/methods_metrics.php

# County level Median SOS: 2001-2013 (MODIS)



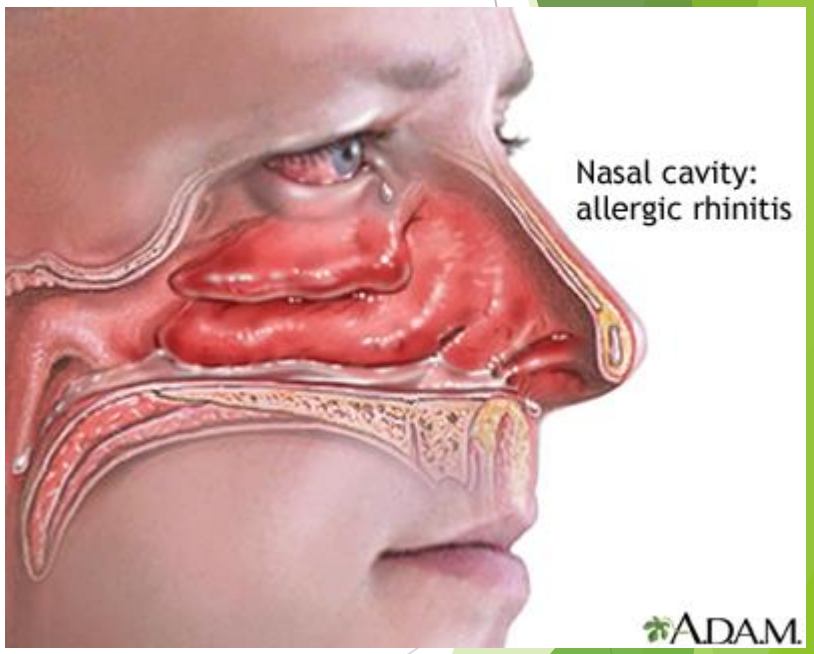
# Health Data

- National Health Interview Survey (NHIS)
  - Monitored the health of U.S. since 1957
  - Largest and principal source of information on the health of the civilian noninstitutionalized population

- Survey Methodology
  - Cross-sectional household interview survey
  - Samples and interviews continuously throughout each year
  - Sampling plan follows a multistage area probability design that permits the representative sampling of households and noninstitutional group quarters (e.g., college dormitories)

# Health Outcome: Allergic Rhinitis (Hay Fever)

- Roughly 8% of US adults suffer from Hay Fever (17.6 million)
- $12 billion every year on medical expenses for hay fever




# Methodology

- Merge NHIS data with MODIS Phenology by county FIPS and year
  - Outcome: Allergic rhinitis
  - Exposure: Changes in onset of spring
  - Time period: 2001-2013
  - ~400k respondents
- Statistical Analysis:
  - The county SOS deviations were categorized into five categories of exposure
    - Very Early (>3 wks early)
    - Early (1 to 3 wks early)
    - Normal (within 1 week: REFERENCE)
    - Late (1 to 3 wks later)
    - Very Late (> 3wks later).
  - Logistic regression using SUDAAN to accounts for the complex clustered sample design of the NHIS

# Demographic Characteristics

| Demographic Charecterstics | | Hay Fever Status | | | |
|---|---|---|---|---|---|
| | | NO | | YES | |
| | | N | Weighted % | N | Weighted % |
| Age | | | | | |
| | 18-34 | 88560 | 31.7 | 4895 | 20.2 |
| | 35-49 | 81896 | 27.9 | 8962 | 35.2 |
| | 50-64 | 70301 | 23.6 | 8013 | 30.1 |
| | >=65 | 60926 | 16.9 | 4695 | 14.5 |
| Race/Ethnicity | | | | | |
| | NonH White | 188344 | 70.3 | 18686 | 77.7 |
| | NonH Black | 46566 | 11.9 | 3348 | 9.1 |
| | Hispanic | 50636 | 12.8 | 3191 | 8.6 |
| | Other | 16137 | 5.0 | 1340 | 4.7 |
| Poverty | | | | | |
| | Povery Ratiio <1 | 50792 | 12.8 | 3660 | 10.1 |
| | Povery Ratiio 1 to 2 | 63325 | 18.8 | 4675 | 15.1 |
| | Povery Ratiio 2 to 4 | 90579 | 30.8 | 7507 | 28.8 |
| | Poverty Ratio >4 | 96987 | 37.7 | 10723 | 46.0 |
| Timing of onset of greenness | | | | | |
| | Spring | 242974 | 82.3 | 21283 | 81.6 |
| | Summer | 18966 | 6.0 | 1578 | 5.6 |
| | Fall | 13203 | 3.8 | 1316 | 4.5 |
| | Winter | 26540 | 7.9 | 2388 | 8.4 |
| Changes in Plant Phenology | | | | | |
| | > 3 wks early | 15844 | 4.7 | 1531 | 5.1 |
| | >1-3 wks early | 54392 | 18.0 | 4562 | 17.2 |
| | 1 wk early - 1 wk late | 174140 | 59.5 | 15141 | 59.1 |
| | >1-3 wks later | 35366 | 11.2 | 3335 | 11.8 |
| | > 3 wks later | 21941 | 6.6 | 1996 | 6.9 |

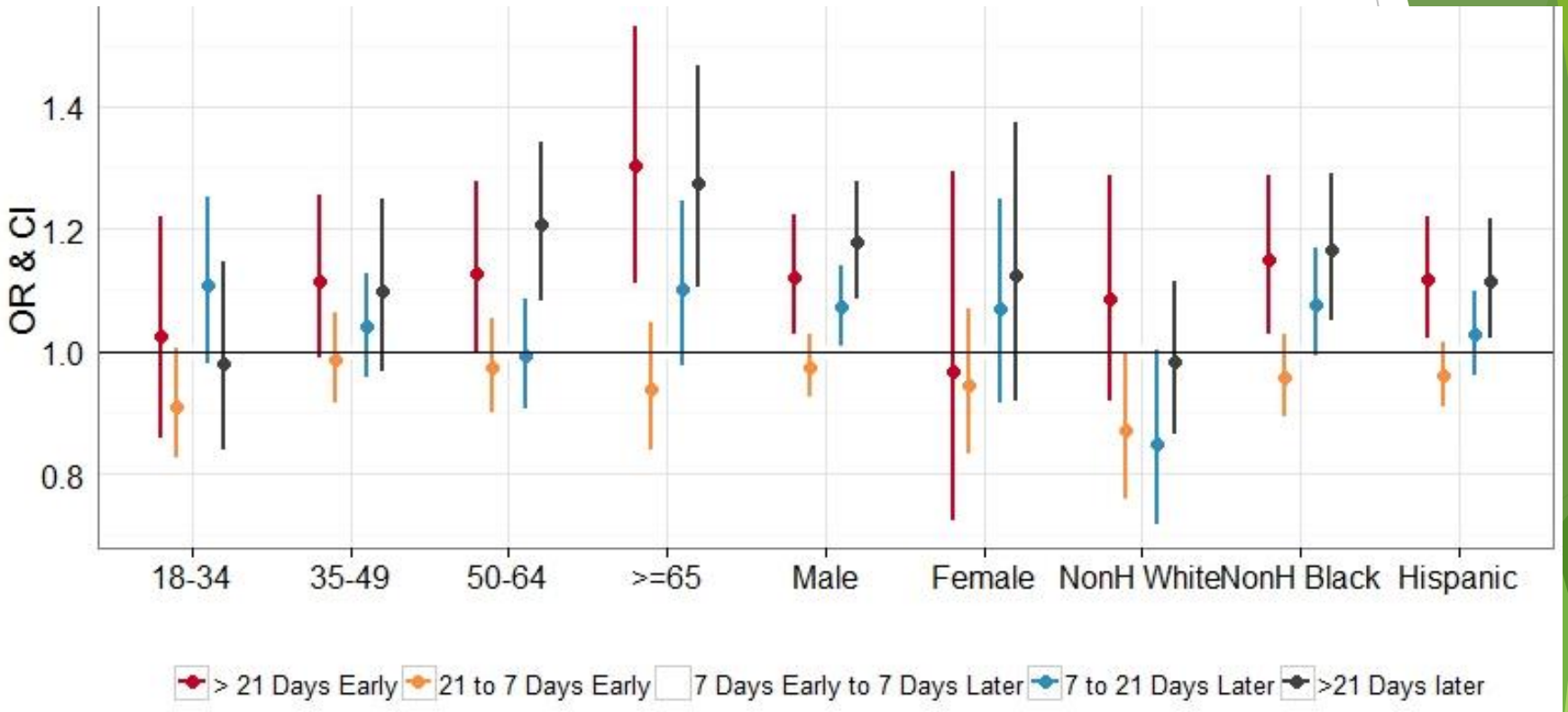
# Results

| | OR | 9%% CI | | OR[1] | 95% CI |
|---|---|---|---|---|---|
| Changes in Plant Pnenology | | | | | |
| > 3wk Early | 1.13 | 1.05-1.22 | | 1.14 | 1.03-1.27 |
| 1-3 wk Early | 0.96 | 0.92-1.00 | | 0.95 | 0.9-1.00 |
| 1 wk early to 1 wk late | 1.00 | REF | | 1.00 | REF |
| 1-3 wk Late | 1.05 | 0.99-1.11 | | 1.05 | 0.99-1.12 |
| >3 wk Late | 1.14 | 1.06-1.21 | | 1.18 | 1.05-1.32 |
| Age Groups | | | | | |
| 18-34 | 1.00 | REF | | 1.00 | REF |
| 35-49 | 1.91 | 1.82-2 | | 1.86 | 1.76-1.96 |
| 50-64 | 1.90 | 1.81-1.99 | | 1.85 | 1.75-1.95 |
| >=65 | 1.32 | 1.25-1.39 | | 1.25 | 1.17-1.32 |
| Race/Ethnicity | | | | | |
| NonH White | 1.42 | 1.34-1.5 | | 1.39 | 1.29-1.5 |
| NonH Black | 1.05 | 0.98-1.13 | | 1.04 | 0.95-1.14 |
| Hispanic | 1.00 | REF | | 1.00 | REF |
| Other | 1.14 | 1.04-1.26 | | 1.11 | 0.99-1.25 |
| Sex | | | | | |
| Male | 1.00 | REF | | 1.00 | REF |
| Female | 1.30 | 1.26-1.34 | | 1.29 | 1.25-1.34 |
| Education | | | | | |
| Less HS | 1.00 | REF | | 1.00 | REF |
| HS | 1.37 | 1.32-1.42 | | 1.38 | 1.32-1.43 |
| College | 1.53 | 1.46-1.6 | | 1.54 | 1.46-1.62 |
| > College | 1.71 | 1.62-1.8 | | 1.72 | 1.62-1.83 |
| 1: Springtime Interview only | | | | | |

Adjusted for Age, Race, Gender, Education, Insurance, Rural-Urban

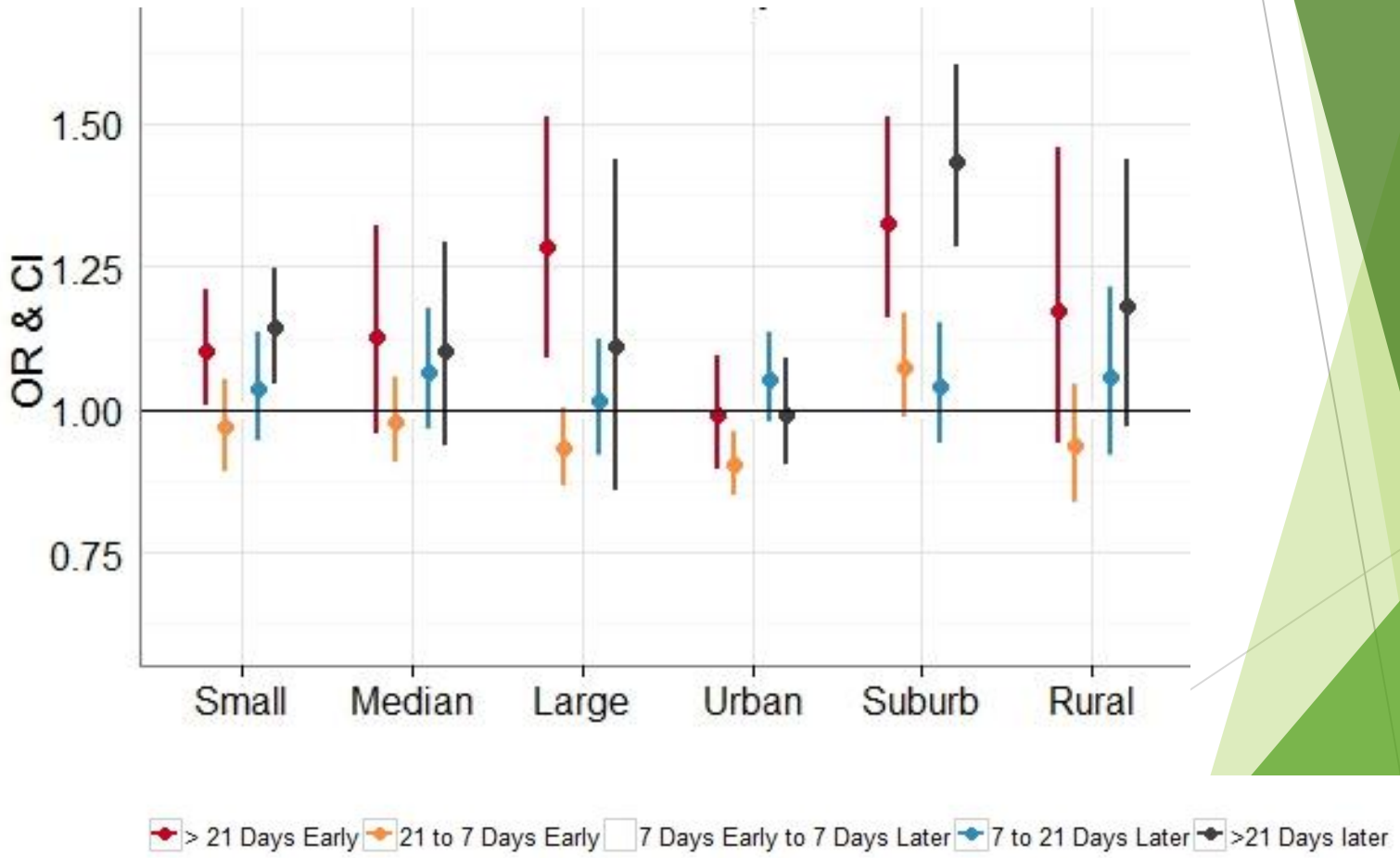
# Hay Fever & Phenology: Results

by Demographic Characteristics



# Hay Fever & Phenology: Results

by County Size & Urban/Rural Status



# Hay Fever & Phenology: Summary

- Application of remote sensing in existing health datasets enables to apply novel exposure metric.

- Allows us to ask new sets of questions that are beyond the scope of the original datasets.

# Hay Fever & Phenology: Summary

- ***Side note:*** Key determinants of exposure:
  - Frequency of contact to the agent
  - Duration of contact to the agent
  - Concentration of agent in the environment.
- Earlier onset of spring does appears to be a risk factor → Longer Duration of Exposure to pollen?
- Later onset of spring also appears to be a risk factor → More intense exposure within short period of time?

# Local Examples: Linking Extreme Event Data with Human Health

# Framing the problem

- In response to our changing climate, extreme events will become:
  - More frequent
  - More intense
  - Longer lasting

  (Field et al. 2012)

- Question: How does frequency of extreme events will impact **Human Health**?

# Local Examples: Extreme Event and Adverse Health in MD

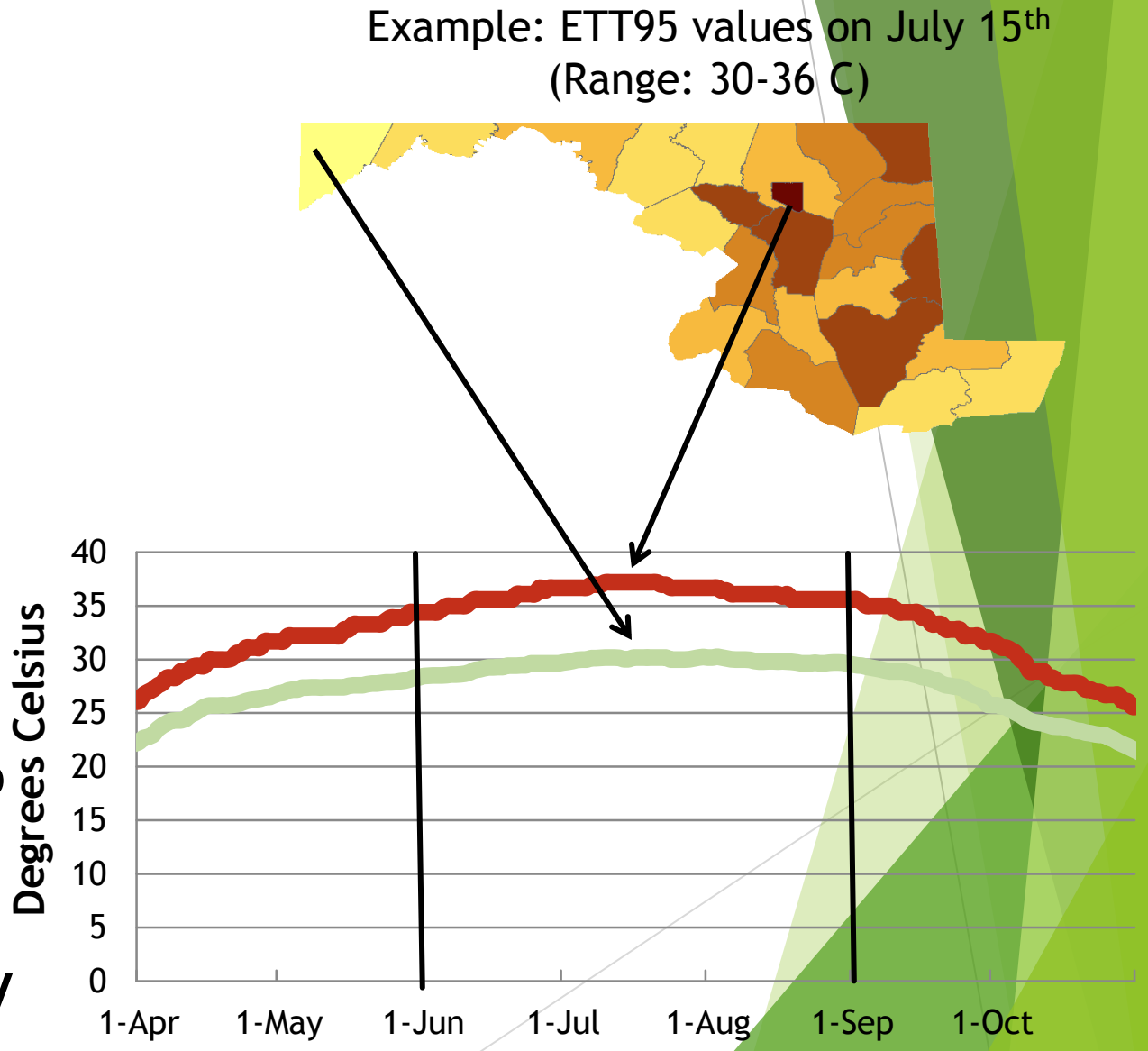
- Allergic Disease: Asthma Hospitalization in MD
- Cardiovascular Disease: Heart Attack Hospitalization in MD
- Foodborne Illness: *Salmonella* Infection in MD

# Demographic Characteristics of Health Data (2000-2012)

| CHARACTERISTICS | Asthma Hospitalization | | Heart Attack Hospitalization | | Salmonellosis | |
|---|---|---|---|---|---|---|
| | # of Cases | % of Cases | # of Cases | % of Cases | # of Cases | % of Cases |
| Total | 115,923 | 100 | 138,665 | 100 | 9,529 | 100 |
| Age Group | | | | | | |
| Under 5 | 18,043 | 16 | 58,036 | 42 | 2,380 | 25 |
| 5 to 17 | 16,649 | 14 | 80,629 | 58 | 1,661 | 17 |
| 18 to 64 | 59,462 | 51 | | | 4,462 | 47 |
| 65 and older | 21,768 | 19 | | | 979 | 10 |
| Gender | | | | | | |
| Female | 70,695 | 61 | 59,849 | 43 | 5,023 | 53 |
| Male | 45,226 | 39 | 78,812 | 57 | 4,475 | 47 |
| Race/Ethnicity | | | | | | |
| Non-Hispanic White | 47,151 | 41 | 95,555 | 69 | 3755 | 39 |
| Non-Hispanic Black | 58,347 | 50 | 28,293 | 20 | 2,509 | 26 |
| Hispanic | 3,047 | 3 | 1,632 | 1 | 515 | 5 |
| Other | 3,479 | 3 | 5,987 | 4 | 293 | 3 |
| Unreported | 3,899 | 3 | 7,198 | 5 | 2,457 | 26 |
| Season | | | | | | |
| Winter | 30,436 | 26 | 36,511 | 26 | 1,377 | 15 |
| Spring | 31,103 | 27 | 35,460 | 25 | 1,853 | 19 |
| Summer | 20,776 | 18 | 32,670 | 24 | 3,777 | 40 |
| Fall | 33,608 | 29 | 34,024 | 25 | 2,520 | 26 |

# Extreme Heat Events in MD

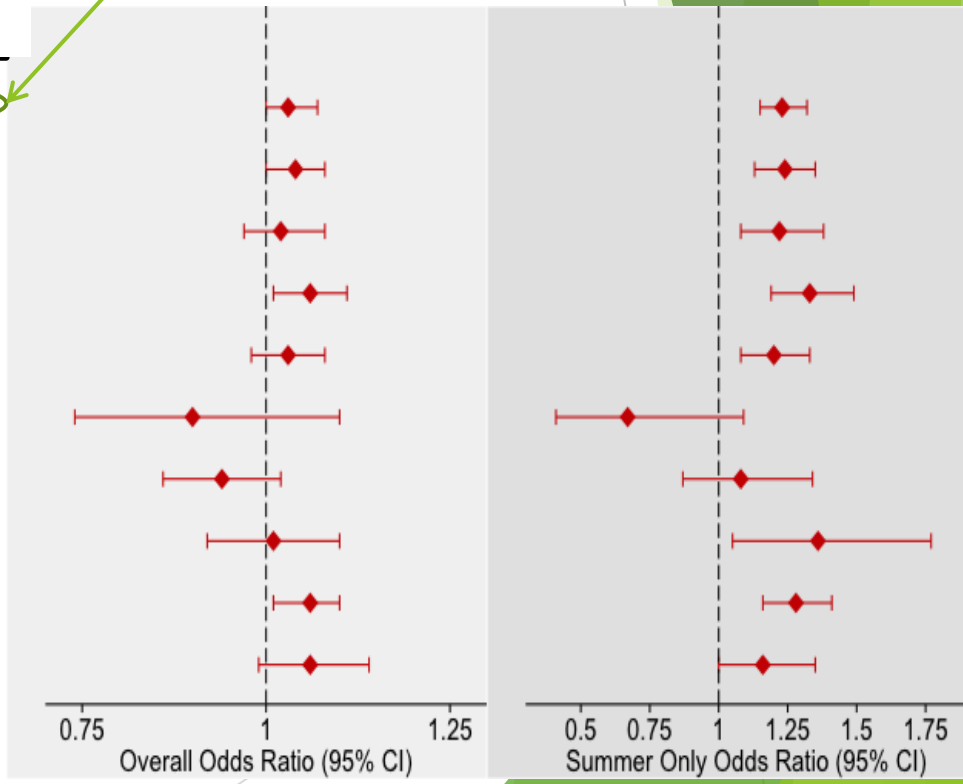
- Location specific thresholds for identifying extreme event generated using weather data from 1960-1989.
- Threshold used to define extreme heat varies by county and by day



# Extreme Heat Events and Risk of ER Visit for Asthma

Related to 1 day increase in extreme heat event

| Characteristics | Subgroups | Overall OR (95%CI | Summer Only OR (95%CI) |
|---|---|---|---|
| All | All of Maryland | 1.03 (1.00, 1.07) | 1.23 (1.15, 1.32) |
| Gender | Female | 1.04 (1.00, 1.08) | 1.24 (1.13, 1.35) |
| | Male | 1.02 (0.97, 1.08) | 1.22 (1.08, 1.38) |
| Race/Ethnicity | White | 1.06 (1.01, 1.11) | 1.33 (1.19, 1.49) |
| | Black | 1.03 (0.98, 1.08) | 1.20 (1.08, 1.33) |
| | Hispanic | 0.90 (0.74, 1.10) | 0.67 (0.41, 1.09) |
| Age Group | 0 to 4 | 0.94 (0.86, 1.02) | 1.08 (0.87, 1.34) |
| | 5 to 17 | 1.01 (0.92, 1.10) | 1.36 (1.05, 1.77) |
| | 18 to 64 | 1.06 (1.01, 1.10) | 1.28 (1.16, 1.41) |
| | 65 and over | 1.06 (0.99, 1.14) | 1.16 (1.00, 1.35) |




*Soneja et al 2016*

# Differences in Risk of Hospitalization for Asthma Related to Extreme Heat Event

| County/State | Season | OR (95% Confidence Interval) |
|---|---|---|
| Maryland | Summer | 1.22 (1.15 – 1.33) |
| Baltimore City | Summer | 1.36 (1.14 – 1.64) |
| Prince George's County | Summer | 1.20 (1.01 – 1.41) |
| Washington County | Summer | 1.76 (1.09 – 2.84) |
| Wicomico County | Summer | 1.22 (0.77 – 1.94) |

# Exposure to Extreme Heat Event and Risk of Hospitalization for Heart Attack (2000-2012)

| Characteristic | Cases | Extreme Heat Event OR and 95% CI |
|---|---|---|
| Overall Model | 32,670 | 1.11 (1.05 – 1.17) |
| Gender | | |
| Male | 18,722 | 1.12 (1.05 – 1.21) |
| Female | 13,948 | 1.09 (1.00 – 1.19) |
| Age | | |
| Age 18-64 | 14,067 | 1.10 (1.02 – 1.20) |
| Age >=65 | 18,603 | 1.11 (1.04 – 1.20) |
| Race | | |
| Non-Hispanic White | 22,343 | 1.09 (1.02 – 1.16) |
| Non-Hispanic Black | 6,730 | 1.27 (1.12 – 1.44) |

Analysis restricted to summer months only

# Differences in Risk of Hospitalization for Heart Attack Related to Extreme Heat Across Counties

| County/State | Summer Only Odds Ratio 95% CI) |
|---|---|
| Maryland | **1.11 (1.05, 1.17)** |
| Baltimore City | **1.43 (1.16, 1.75)** |
| Prince George's County | 1.06 (0.91, 1.24) |
| Wicomico County | 1.00 (0.74, 1.35) |
| Washington County | 0.96 (0.71, 1.29) |

# Extreme Events and Salmonellosis

| Characteristics | Extreme Heat Event | Extreme Precip. Event |
|---|---|---|
| **Overall Model** | 1.041[1.013-1.069] | 1.056[1.035-1.078] |
| **Season** | | |
| Spring | 0.961[0.926-0.997] | 1.013[0.984-1.042] |
| Summer | 1.045[1.014-1.077] | 1.017[0.989-1.046] |
| Fall | 1.004[0.964-1.045] | 1.037[1.015-1.060] |
| Winter | 0.962[0.928-0.998] | 1.012[0.972-1.053] |
| **Geographical Location** | | |
| Coastal Counties | 1.051[1.023-1.081] | 1.071[1.044-1.099] |
| Non-Coastal Counties | 1.015[0.977-1.055] | 1.036[1.017-1.054] |

Considerably larger effect observed in coastal counties compared to non-coastal counties

*Jiang et al 2015*

# Summary

- In Maryland, exposure to extreme heat increases risk of hospitalization for Heart Attack and Asthma.
- Both extreme heat and extreme precipitation increase risk of *Salmonella* infection.
- The risk of *Salmonella* infection is higher in coastal communities.

# Acknowledgement


UMD-SPH

- Dr. Chengsheng Jiang
- Ms. Crystal Romeo
- Dr. Raghu Murtugudde
- Dr. Amy Sapkota
- Dr. Sutyajeet Sonja

DHMH

- Dr. Cliff Mitchell
- Dr. David Blythe

NCHS

- Dr. Jennifer Parker
- Dr. Lara Akinbami

USDA

- Dr. Lew Ziska

JHSPH

- Dr. Frank Curriero

BAERI/NASA Ames

- Dr. Sangram Ganguly

Funding: NIEHS, CDC